CHEMISTRY 20 -- UNIT 3: CHEMICAL BONDING
TOPIC 1: BASICS OF BONDING

LESSON 1.1: INTRODUCTION TO BONDING

1. ***What is a bond?***

2. ***What is a Covalent Bond?***

3. ***What is an Ionic Bond?***

4. ***What is a Metallic Bond?***

5. ***What is a Network Covalent Bond?***

6. ***What happens when a covalent bond between Chlorine and Chlorine is formed?***

7. ***What happens when an ionic bond between Sodium and Chlorine in formed?***

8. ***Illustrate the attractions within (intramolecular) and between (intermolecular) water molecules.***

9. ***Properties of the four main type of bonds***

	Molecular	***Ionic***	***Metallic***	***Network Covalent***
State				
Conductivity				
Solubility				
Color				
Parts/Components				
Melting point				
Other				

10. ***Summary: Test yourself by filling in the blanks below.***
    - A bond is an _______________ force of __________________
    - A covalent bond is the attraction of __________ in one atom and ____________ in other atom. (INTRAMOLECULAR CD)
    - An ionic bond is the attraction between __________ and _________ (IONIC CD)
    - Also _________ and __________ solids have electrostatic forces of attraction.
    - Electrostatic forces of attraction also hold ___________ together (INTERMOLECULAR CD)
    - When bonding forms energy is usually ____________ (exothermic)
    - When bonds form, more stable _______________ arrangements result.

LESSON 1.2: ATOMIC STRUCTURE (UNDER "BASICS OF BONDING" ON ANY CD)

1. ***Two dimensional model of the atom***. (Bohr's model)

Draw energy level diagrams and label the nucleus, protons, electrons, neutrons and valence electrons for the following atoms and ions. Negative ions (anions) gain electrons.

a) $^{20}_{10}Ne$ b) $^{14}_{7}N$ N^{3-} c) $^{7}_{3}Li$ Li^{+} d) $^{11}_{5}B$

8e-
2e-
10p+
10n
Ne

2. ***General Properties of groups of atoms on the periodic table.***
   a) Noble gases:
   b) Alkali metals:
   c) Alkaline earth:
   d) Halogens:
3. ***Three dimensional model of the atom***. (Quantum mechanics model)
4. ***Electron Configuration (Not part of the CD ROM.)***

There are principle energy levels with sublevels. Each sublevel has a different cloud shape and can hold a different number of electrons.

The principle energy levels fill the sublevels as follows:

Energy Level	**S shell hold 2e- spherical**	**P shell hold 6e- dumbbell**	**D shell hold 10e - complex**	**F shell hold 14e- complex**
1	$1s^2$			
2	$2s_2$	$2p^6$		
3	$3s^2$	$3p^6$	$3d^{10}$ (period 4 atoms)	
4	$4s^2$	$4p^6$	$4d^{10}$ (period 5 atoms)	$4f^{14}$ (period 6)
5	$5s^2$	$5p^6$	$5d^{10}$ (period 6 atoms)	$5f^{14}$ (period 7)
6	$6s^2$	$6p^6$	$6d^{10}$ (period 7 atoms)	
7	$7s^2$	$7p^6$ (future)		
	Families 1-2 (alkali & alkaline)	Families 13-18 (halogen & nobel gases)	Families 3-12 (Transition metals)	Rare Earths

gallium -$3d^{10}$ $4s^2$ $4p^1$

*The large number in front represents the energy level. Shell d belongs to the 3rd level and shell s & p belong to the 4th level.

*The small superscript number represents the number of electrons in each shell. Shell d has 10 electrons

- The total number of valence electrons can be determined by adding the superscripts together.

LESSON 1.3: LEWIS DOT DIAGRAM OR ELECTRON DOT DIAGRAMS ("BASICS OF BONDING")

Gilbert Lewis (1875 - 1946) developed a scheme for drawing atoms with valence electrons shown as dots called Lewis Structures or Electron dot diagrams. (see page 300 of the Addison Wesley Chemistry Text for a chart of dot diagrams for several elements.)

1. ***Electron dot diagrams:*** ____

____

2. ***Rules for Drawing Lewis structures for elements.***
   - Write the **symbol** to represent the nucleus & the innermost energy levels. Determine the number of valence electrons by the elements **group number**.
   - Place a dot to represent each **valence electron**. Start by placing one dot by each side of the element symbol. If necessary, start filling in the second dot to a maximum of **8 dots**(octet). Exception: **hydrogen and helium**

EXAMPLES:

Neon:

Fluorine:

Aluminum:

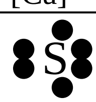
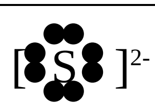
Acceptable | Unacceptable

Nitrogen:

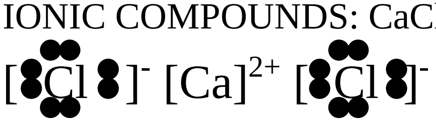
Carbon:

3. ***Lone pairs and bonding electrons***
   - Lone pairs: ____
   - Bonding electrons: ____

4. ***Rules for Lewis structures for simple ions.***
   1. Draw the symbol
   2. Add a dot for each valence electron
   3. Add a dot for each electron gained OR remove a dot for every electron lost. Place the symbol in square brackets and place the charge outside of the brackets.

Element or Ion	**Electron Dot Diagram**	**Number of valence electrons**	**Number of bonding electrons**	**Number of lone pairs**
Calcium (Ca)	● Ca ●	2	2	0
calcium ion (Ca^{2+})	$[Ca]^{2+}$	0	0	0
Sulphur (S)		6	2	2
Sulphide (S^{2-})		8	0	4

IONIC COMPOUNDS: $CaCl_2$



LESSON 1.4: ELECTRONEGATIVITY ("BASICS OF BONDING")

1. Electrostatic forces of attraction exist between the **protons** and **electrons** of an atom and are inversely proportional to the **size** of the atom. This force determines the amount of energy required or released when losing or gaining an electron. This force of attraction also relates to the electronegativity of an atom.
2. Definition of electronegativity: ____

   ____
3. Relative scale of electronegativity developed by Linus Pauling
   - electronegativities are found on the periodic table.
   - In the compound HF, the electronegativity of H is _______ and F is ________
   - F has twice the electronegativity of H and therefore ______________ electrons.
   - The element(s) with the least electronegativity is(are) ___________
   - The elements(s) with the greatest electronegativity is(are)_____________

   a) What happens to the electronegativity values for the elements of a family as the number of filled energy levels increases? ___________________________________

      Why? ____

   b) What happens to the electronegativity values for the elements of a period as the number of valence electrons increases? ______________________________________

      Why ? _______________________ _______________________________________

   c) What type of bond forms when the electronegativity values are the same?

      The electrons are **shared/transferred** **(circle)** in this type of bond. Ie) chlorine gas

   d) What type of bond forms when the electronegativity values are significantly different.

      The electrons are **shared/transferred(circle)** in this type of bond. Ie) sodium chloride

   e) Do NOBLE GASES, CARBON and SILICON have an electronegativity? (look at your periodic table)

      Why? ____

4. Bond type generalizations based on electronegativity
   - If the electronegative difference between two bonded atoms is equal or greater than 1.7 the bond is **ionic**.
   - If the electronegativity difference between two bonded atoms is less than 1.7 than the bond is **polar covalent** .
   - If the electronegativity difference between two bonded atoms is O than the bond is **covalent (non-metals) or metallic (metals).**

TOPIC 2: MULTIMEDIA CHEMISTRY INTRAMOLECULAR IONIC

OVERVIEW

1. ***Table Salt Mystery***

   - How do toxic elements sodium and chlorine combine to form sodium chloride, table salt - essential to our diet?

2. ***Introduction - In this topic you will:***

   - Investigate ionic properties
   - Examine ionic reactions
   - Examine an industrial plant
   - Meet Charles Hall

3. ***Prerequisites - It is essential that you have a complete understanding of***

   - Atomic structure
   - Naming ionic compounds
   - Energy shell diagrams
   - Electron dot diagrams
   - AND Bond types

LESSON 2.1: IONIC BOND

1. ***Introduction***

   - An ionic bond is the complete electron transfer and involving the electrostatic attraction between positive and negative ions.
   - Vocabulary: anion, cation, electron, simple composition reaction(formation), ion, ionic bond, ionic compound, oxidation, polyatomic ion, reduction

2. ***Where are ionic compounds found***

   - Common Uses: fertilizers (ammonium nitrate), antacid (calcium hydroxide), lime (calcium oxide) and rust (iron (III) oxide)
   - Naturally occurring as minerals: halite (NaCl), fluorite (CaF_2), Calcite($CaCO_3$), pyrite (FeS_2), hermatite (Fe_2O_3)

3. ***The role of metals and nonmetals***

   - Ionic compounds are made of metals (left side of staircase) and nonmetals (right side of staircase)
   - Identify the ionic compounds in the following list: MgO, CaF_2, NO_2, $MgCO_3$

4. ***The transfer of electrons***

   - Electrostatic attraction of opposite charges draws the ions together

Lewis Diagram of atoms	Lewis Diagram of ions with charges	Atom that lost electrons	Atom that gained electrons
NaCl			
MgO			

5. ***Anion and cation formation***

Compound	Cation formation equation (losses electrons)	Anion formation equation (gains electrons)
NaCl		
MgO		

LEO goes GER:

6. ***NaCl***

- Reaction: (ID the metal, nonmetal, ionic compound, & the type of reaction.)

- Evidences of a reaction:
- Add energy to the correct side of the equation.
- Balance the reaction. Translate to words.

7. ***MgO***

- Reaction: (ID the metal, nonmetal, ionic compound, & the type of reaction.)

- Evidences of a reaction:
- Add energy to the correct side of the equation.
- Balance the reaction. Translate to words.

8. ***Al_2O_3***

- Reaction: (ID the metal, nonmetal, ionic compound & the type of reaction.)

- Evidences of a reaction:
- Add energy to the correct side of the equation.
- Balance the reaction. Translate to words

9. ***Summary***

LESSON 2.2: FORMULA UNITS

1. ***Introduction:***
   - You will discover the formula unit using dot diagrams & ionic charges. You can verify the formula unit by examining the crystal lattice
   - DEFINITIONS:

     Crystal lattice:

     Formula Unit:

2. ***Crystal Lattices***
3. ***NaCl- Dot diagram ___________(use your head)***
   - One electron is transferred forming the formula unit NaCl
   - Ionic bond is electrostatic attraction between positive and negative ions. The net charge must be zero. Total cation charge plus total anion charge must equal zero. $1^{+} + 1^{-} = 0$
   - The crystal lattice verifies the formula unit. 6 sodiums surround each chlorine and 6 chlorines surround each sodium, which reduces to a 1:1 ratio
4. ***CaF_2: Dot diagram _______________ (use your head)***
   - Only one of calcium's two electrons is transferred to one fluorine. Two atoms of fluorine are needed to accept the two electrons. The formula unit CaF_2 results.
   - Total net charge = (# of cations x charge) + (# of anions x charge) = 0

     ____ = 0
   - Cations to anions in the crystal lattice:____________reduced:___________
5. ***MgO: Dot diagram _______________________ (use your head)***
   - Electrons transfer: ____
   - Total net charge = _________________________________ = 0
   - Cations to anions in the crystal lattice: ________________________________
6. ***Al_2O_3: Dot diagram ___________________________ (use your head)***
   - Electrons transfer:____
   - Total net charge = __________________________________ = 0
   - Cations to anions in the crystal lattice: ______________________________
7. ***Summary***

LESSON 2.3: HALF REACTIONS (Optional)

1. ***Introduction***
   - You will be able to write balanced half reactions, write net redox reactions, relate redox reactions to industry, and explain the conservation of electrons in redox reactions.
   - Vocabulary: diatomic, half reaction, net redox reaction, oxidation, redox reaction, reduction, total ionic equation
2. ***Oxidation and reduction***
3. ***Net redox reactions***
4. ***Balancing 1/2 reactions***
5. ***Writing redox reactions***
6. ***Chloralkali plant***
7. ***Perspectives***
8. ***Summary***

LESSON 2.4: PHYSICAL PROPERTIES

1. ***Introduction***
   - You will be able to list the properties of ionic compounds and identify ionic compounds based on these properties.
   - Vocabulary: conductive, conductivity apparatus, crystal lattice, electrolyte, insoluble, melting point, nonconductive, physical property, solubility
2. ***Melting point, Solubility, Conductivity of solids, Conductivity of liquids, Conductivity of solutions***

Compound	**$LiCl$**	**$Co(NO_3)_2$**	**KI**	**$NaOH$**	**Al_2O_3**	**$NaCl$**	**MgO**	**Conclusions**
Melting point								
Solubility (in water)								
Cond of solids								
Cond of liquids								
Cond of solution								

NOTE: Most Metals are extracted from molten ionic compounds by electrolysis

3. ***The Charles Hall Story***

TOPIC 3: MULTIMEDIA CHEMISTRY INTRAMOLECULAR BONDING

OVERVIEW

Simple and complex chemicals interact in human biological systems. The study of this is called biochemistry. One complex biochemical is hemoglobin - $C_{2954}H_{4508}Fe_4N_{780}O_{806}S_{12}$ with a molar mass of 64,500 g/mol. The bonds that hold hemoglobin together are mostly intramolecular bonds between nonmetals.

LESSON 3.1: COVALENT BOND

1. ***Introduction***
   - Elements exist as atoms (Ne) or molecules ($O_{2(g)}$, $S_{8(s)}$, $C_{60(s)}$).
   - Molecules involve covalent bonding ($CO_{2(g)}$, hemoglobin).
2. ***Definition***
   - A covalent bond involves shared electrons, a stable electron arrangement and lower energy.
   - Only the outer valence shell of electrons are used

Element	***Energy Level Diagram***	***Lewis Structure***
$_8O$		
$_7N$		

   - Noble gases are not reactive, are stable, and thus are found in their elemental state
   - Covalent bonds are formed by the filling the valence electron shell. These bonds follow the octet rule and are stable. The valence electron shell looks like the electron shell of a noble gas.
   - Which noble gas does not follow the octet rule? _______________
   - Example: Chlorine's electron configuration is like _________gas(draw it below)

Fluorine's electron configuration is like __________gas(draw it below)

3. ***Molecular Elements***

Diatomic Elements Sharing A Single Pair

   - Fluorine and chlorine form a single covalent bond. The shared electron pair becomes the __________________ bond
   - Lewis structures may use a dash to show the shared electron pair. Ie)
   - Ball and stick models show bond length and the shape of the molecules. ie)

- Besides fluorine and chlorine the other diatomic elements that share a single pair of electrons are(include a Lewis structure)

- Hydrogen gas has the same electron structure as ___________________

Diatomic Elements With Two Shared Electrons - Double Bond

- How many electron pairs must be shared between oxygen to give each atom a stable octet? _______ Draw the Lewis structure for oxygen gas below.

- Draw the Lewis structure for the sulphur molecule, $S_{8(s)}$

Diatomic Elements With Three Shared Electrons - Triple Bond

- How many electron pairs must be shared between nitrogen to give each atom stable octet? _____________Draw the Lewis Structure for nitrogen gas below.

Match the number of shared electron pairs to the column of elements.

No shared e-	***1 shared e-***	***2 shared e-***	***3 shared e-***	***4 shared e-***
C	N; P	O; S; Se	F; Cl; Br; I	He; Ne; Ar; Kr; Xe

Some molecules are more complex. How many bonds does "Bucky ball" form ? __________

4. Forces

- positive charges repel positive charges; negative charges repel negative charges; positive charges attract negative charges.
- Electron density distribution is ____________________________________
____
- covalent bond is the simultaneous attraction of two nuclei for a shared pair of electrons.
- Bond length is the distance between the centers of two atoms in a covalent bond, where the force of attraction and repulsion are balanced and the potential energy is at a minimum.
- Draw the Energy vs Distance graph for two hydrogen atoms.

- Draw the stable electron density distribution for hydrogen.

- Which has the greatest bond distance - H_2 or Cl_2? Why?

- Compare the forces acting within covalently bonded molecules and its effect on the bond length of hydrogen and chlorine. Include: ***attractive force, repulsive force, minimum energy and number of electrons.***

5. Comparison between Ionic and Molecular Compounds

	Ionic	Molecular
Description		
Formation Reaction		
Formation Theory		
Formula		

6. Review

LESSON 3.2: LEWIS STRUCTURE

1. ***Introduction***
2. ***Review Of The Basics***
   - Lewis structure provides a visual representation of the ______________ in a molecule.
   - Pairs of dots or dashes between atoms represent ______________________
   - Pairs of dots attached to ONLY one atom represent __________________
   - Lewis structures do not imply the ____________________________
3. ***Central Atoms***
   - Central atoms are the atom(s) in the middle of a molecule.
   - Pendant atoms are the atoms(s) on the outside.
   - Guidelines
     1) STABLE Atoms usually have 8 electrons surrounding them - called an OCTET.

        Exceptions: Hydrogen (H) only has 2; Beryllium (Be) has 4; Boron (B) has 6; Sulphur can have 10; Selenium (Se) has 12
     2) Electrons around an atom equals the sum of the ______________________ and the ______________________________________
     3) Atoms with ________________________ bonding electrons are the central atoms, while atoms with ____________________ bonding electrons are the pendant atoms.
4. ***Simple Molecules***
   - RULES for drawing Lewis Dot Diagrams for Molecules.
     1) Pick and draw the Lewis Dot Diagram for the central atom(s)
     2) Draw the Lewis Dot Diagrams for the pendant atoms around the central atom. Share bonding electrons between central and pendant atoms.
     3) Verify that each atom has ______electrons surrounding it (octet) except hydrogen.
   - Examples

     NI_3

     H_2S

     CH_2F_2

     CCl_4

     H_2O

     PCl_3

     CH_3Cl

     NH_3

- Circle the valid statements for X:Y:Z:

X shares one pair of electrons.	Atom Y is from group IV (14)
X is surrounded by two electrons	Atom Z is from group VII (17)
Y has four shared pairs of electrons	Atom Y is sulphur
Z has three unshared pairs of electrons	Atom Z is hydrogen or chlorine

5. *Multiple Bonds*

- Same Rules for drawing Lewis Dot Diagrams except:
  - Combine unshared bonding electrons into double or triple bonds.
- Examples

CO_2

HCN

C_2H_2 - ethyne or acetylene

CS_2

CH_2O - methanal

- Exceptions:

SO_2	**Acceptable Structure (But not viable)**	**Two Resonances (two acceptable Lewis Diagrams)**	**One Resonance Hybrid (one overall drawing)**

6. *Polyatomic Ions*

- Same Rules for drawing Lewis Dot Diagrams Except:
  - add or remove electrons based on charge and place ion in square brackets with charge on outside.

- Examples:

  SO_4^{2-}

When a bond is formed by the sharing of electrons and both electrons come from the same atom, we call it a ____________________.

NH_4^+

CO_3^{2-}

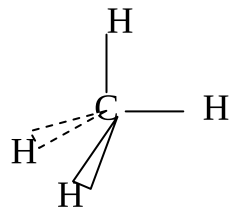
7. *Review*

CO

LESSON 3.3: MOLECULAR GEOMETRY (Use Molecular Explorer (ME) Lessons CD)

1. 3d Perspective

- Molecules have 3-D shapes, which look different from different perspectives.
- **Stereochemistry** is the study of the 3-D shapes of molecules
- **VSEPR** - Valence Shell Electron Pair Repulsion: A theory used to study 3-D shapes.
- When drawing 3-D shapes on paper scientists use the following format.



1) Orient as many atoms in the plane of the paper Include Central atom. Use a line to represent these.
2) Atoms coming out of the paper, use a triangle
3) Atoms behind the paper, use a dotted triangle

- Start Molecular Explorer CD and test your 3-D perceptions.

2. Electron Pair Repulsion

- Orientation of two electron pairs (charges):
- Orientation of three electron pairs (charges):
- Orientation of four electron pairs (charges):
- $BeCl_2$ Ball & Stick model: Shape:
- BF_3 Ball & Stick model: Shape:
- CH_4 Ball & Stick model: Shape:

3. Pendant Atom Orientation *Optional shapes for this class.

- If the central atom does **not have any lone pairs**, then the shape of the molecule can be determined by the number of pendant atoms. Include the angle between pendant atoms for the examples below.
- One pendant atom:
  - Ie) CO, HF
- Two pendant atoms:
  - Ie) $BeCl_2$, HCN, NO_2^-
- Three pendant atoms:
  - Ie) BF_3, CH_2O, H_3O^+, CO_3^{2-}
- Four pendant atoms:
  - Ie) CH_4, NH_4^+
- Five pendant atoms:*
  - Ie) PCl_5
- Six pendant atoms:*
  - Ie) SF_6
- Seven pendant atoms:*
  - Ie) IF_7

4. ***High Electron Density Regions***

- Lone pairs influence the shape of molecules. High electron density regions include lone pairs and bonding regions. Double & Triple bonds are ***one*** density region.
- Molecular Geometry is the shape formed by the pendant atoms
- Electronic Geometry is the shape formed by the electrons density regions.
- Shapes with four bonded pairs of electrons:

  Ie) CH_4

- Shape with three bonded pairs of electrons and one lone pair:

  Ie) NH_3

- Two bonded pairs of electrons and two lone pairs:

  Ie) H_2O

5. ***Electronic & Molecular Geometry (look above)***
6. ***Shapes Within Large Molecules***

- Larger Molecules can have two or more shapes surrounding the central atoms.
- Examples

  Methanol

  Ethanol

  Propyne

  Ethanoic acid

Summary:

LESSON 3.4: POLARITY

1. ***Introduction: Why learn about polarity? What causes pavement to heave, severe frostbite or water to expand when it freezes?***
2. ***Definition***
   - A polar compound carries a ____ and a ______________________________ ie) ___________________
   - A nonpolar compound does not carry a ______________________________________ Ie) _______________________
3. ***Bond Dipoles – notation that indicates a region of positive charge and a region of negative charge.***
   - What are the bond dipoles in hydrogen peroxide (H_2O_2)

STRUCTURAL Diagram: Non 3-D diagram using a dash for bonding electrons and not drawing in lone pairs.

H – O	O – O
EN	EN
ΔEN = electrons shift towards the negative region (O)	ΔEN = no shift in electrons
DRAWING BOND DIPOLES	NO BOND DIPOLES

1) **Delta notation**: H – O
2) **Vector notation**: H – O

- What are the bond dipoles for the five covalent bonds, which are given you? Use both notations.

a)

b)

c)

d)

e)

4. Molecular Shapes

- How does the shape of a molecule affect its polarity?

Polar Compounds	Nonpolar Compounds
<u>Water ($H_2O_{(g)}$)</u> VSEPR diagram & shape with bond dipoles: Pendant atoms (similar/different) Vector analysis of bond dipoles (cancel/don’t cancel)	**<u>Tetrachloromethane (CCl_4)</u>** VSEPR diagram & shape with bond dipoles: Pendant atoms (similar/different) Vector analysis of bond dipoles (cancel/don’t cancel)
<u>Difluoromethane</u> VSEPR diagram & shape with bond dipoles: Pendant atoms (similar/different) Vector analysis of bond dipoles (cancel/don’t cancel)	**<u>Methane</u>** VSEPR diagram & shape with bond dipoles: Pendant atoms (similar/different) Vector analysis of bond dipoles (cancel/don’t cancel)
<u>Hydrogen chloride</u> VSEPR diagram & shape with bond dipoles: Pendant atoms (similar/different) Vector analysis of bond dipoles (cancel/don’t cancel)	**<u>Hydrogen gas</u>** VSEPR diagram & shape with bond dipoles: Pendant atoms (similar/different) Vector analysis of bond dipoles (cancel/don’t cancel)
<u>Methanal</u> VSEPR diagram & shape with bond dipoles: Pendant atoms (similar/different) Vector analysis of bond dipoles (cancel/don’t cancel)	**<u>Carbon dioxide</u>** VSEPR diagram & shape with bond dipoles: Pendant atoms (similar/different) Vector analysis of bond dipoles (cancel/don’t cancel)
<u>Ammonia</u> VSEPR diagram & shape with bond dipoles: Pendant atoms (similar/different) Vector analysis of bond dipoles (cancel/don’t cancel)	**<u>Ethene</u>** VSEPR diagram & shape with bond dipoles: Pendant atoms (similar/different) Vector analysis of bond dipoles (cancel/don’t cancel)
<u>Generalization:</u>	**<u>Generalization:</u>**

5. Intricacies

<u>Hydrogen telluride (H_2Te)</u> VSEPR diagram & shape with bond dipoles	**<u>Nitrogen trifluoride</u>** VSEPR diagram & shape with bond dipoles
<u>Water</u> VSEPR diagram & shape with bond dipoles	**<u>Ammonia</u>** VSEPR diagram & shape with bond dipoles

- Why is hydrogen telluride polar when the atoms' electronegativities are the same?

- Why is nitrogen trifluoride not as polar as water and ammonia?

- Is 1-butanol($CH_3CH_2CH_2CH_2OH$) polar or non-polar or both? NOTE: The longer a compound the less affect that the polar regions has.
- Circle the polar region on 1-amino propane - $CH_3CH_2CH_2NH_2$
- Expanding ice pushes up pavement and ruptures cell membranes in frostbite. Water expands when it freezes because it is very _____________ and it forms a unique _______

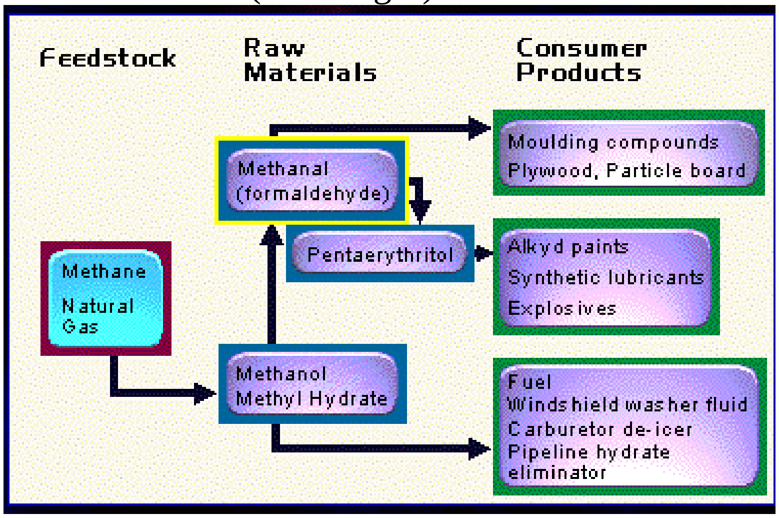
6. Summary

- Polar molecules have a positive region and a negative region
- Bond dipoles are determined by the electronegativity of the two atoms forming a bond.
- Polarity of a molecule is determined by the VSEPR shape, vector addition of bond dipoles and the presence of lone pairs.
- Large molecules have polar and non-polar regions
- Water expands when it freezes because it is very polar and forms a unique crystal.

TOPIC 4: MULTIMEDIA CHEMISTRY INTERMOLECULAR ATTRACTIONS

OVERVIEW

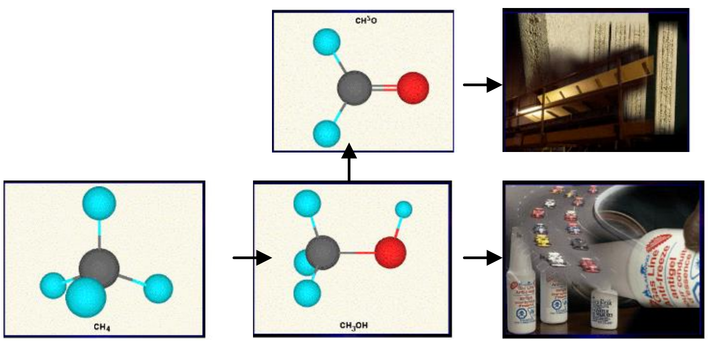
The Petrochemical Industry uses their understanding of molecular properties so they can handle and store chemicals properly. One of these molecular compounds, methane, is used to heat our homes (natural gas) and to make raw materials like methanol & methanal. (See below.)



Methanal's formula is ____________

Pentaerythritol formula is $C(CH_2OH)_4$

Methanol's formula is ___________



LESSON 4.1: FORCES BETWEEN MOLECULES

1. ***Introduction:*** Melting points and boiling points of molecules affect the way they are stored. Methane, methanal and methanol are very similar in their structures, so one would think that their melting points and boiling points would be similar. Put in the actual melting points and boiling points of these molecules in the table below.

Melting & Boiling Points of Methane, Methanol and Methanal

	Methane	Methanol	Methanal
Melting point			
Boiling point			

What causes these differences? ____

2. ***Definition of Intermolecular Attractions***

- Forces that hold atoms together within molecules are called __________________
  Methane has four hydrogen atoms covalent bonded to a central carbon atom. These bonds are called ________________
- Forces that act between covalent molecules are known as ____________________
  Methanol is a liquid at room temperature. The forces that keep the molecules together are called _______________________

- A molecular compound is ____
- The electrostatic forces that hold atoms together within molecules are called _____________________
- Intermolecular attractions are electrostatic forces that ________________________
- ____________ , _____________, & ____________ often act in combination.
- Molecular substances like methane, methanal and methanol have different boiling points. This indicates that the strength and combination of the forces between the molecules is ____________
- The force that does NOT attract one molecule to another is __________________

3. (London) Dispersion Forces

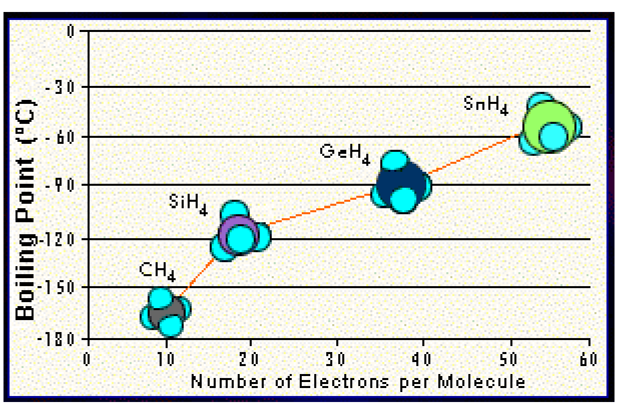
- Dispersion forces can be illustrated using methane, since its low boiling point indicates weak forces of attraction. In the liquid phase, the positive nucleus of one molecule is momentarily attracted to the electron cloud of another molecule and a dispersion force results. Sketch Dispersion between methane molecules below.

- The kinetic energy of molecules affects the strength of dispersion forces. As the kinetic energy decreases the dispersion forces ___________. Dispersion forces are weak intermolecular attractions that only operate over ___________ distances.
- Draw the dispersion forces between helium molecules below.

The instantaneous attraction of _____________ results in _______________

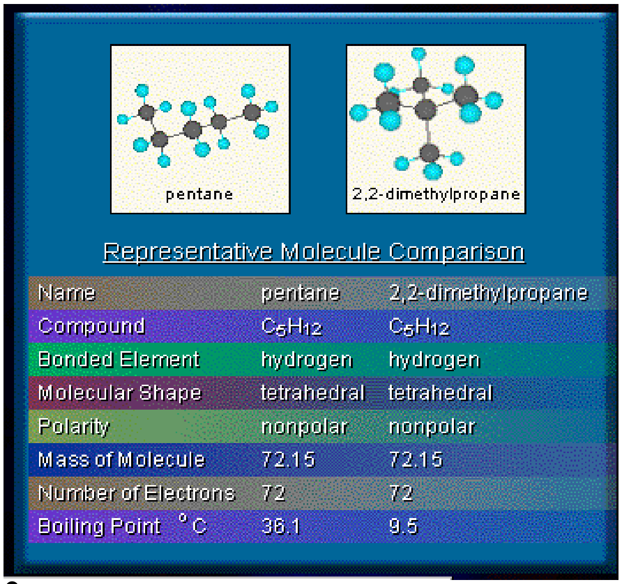
- The strength of attraction between molecules of methane gas is ___________
- Dispersion forces are a result of electrostatic attraction between ________________
- Dispersion forces among molecules tend to be stronger at ____________________

4. Factors affecting Dispersion Forces



- What affect does the **<u>total</u>** number of electrons have on the strength of intermolecular dispersion forces? As the number of electrons in the molecules in the graph increases, the boiling point of the liquids ______________
- As the number of electrons in the molecules increases, the strength of the dispersion forces should ______
- What other variables may explain the increased boiling points? ____

- Therefore the increasing boiling points are caused by the increase in the number of electrons which result in increased molar mass and increased central atom radii.
- Pentane and 2,2-dimethylpropane have the same formula(C_5H_{12}) but different shapes. They are called ____________.



Name	pentane	2,2-dimethylpropane
Compound	C_5H_{12}	C_5H_{12}
Bonded Element	hydrogen	hydrogen
Molecular Shape	tetrahedral	tetrahedral
Polarity	nonpolar	nonpolar
Mass of Molecule	72.15	72.15
Number of Electrons	72	72
Boiling Point °C	36.1	9.5

- According to the data, does mass have an effect on boiling point? ____
- According to the data, does the number of electrons have an effect on the boiling point? _____________
- Why is there a difference in boiling points between pentane and 2,2-dimethyl propane?________________

WHY? The pentane has ______________ Temporary dipoles while 2,2-dimethylpropane have __________ temporary dipoles.

- What effect will increasing the number of electrons in nonpolar molecular substances have on dispersion forces? ________________
- What effect will increasing the mass of molecular substances have on dispersion forces? _______________ Is this a direct relationship?
- Two molecular isomers have identical mass and identical electron numbers but different shapes. The substance that ____________________ will have the higher boiling point.

5. ***Dipole Dipole Forces***

- Dipole-dipoles forces can be illustrated using methanal. The a positive dipole in one methanal is attracted to a negative dipole in another methanal molecule. Sketch a dipole-dipole force below.

- As methanal condenses into a liquid (loses kinetic energy), the dipole dipole forces ____________ .
- Draw the dipole-dipole forces between four hydrogen chloride molecules below. Permanent dipole interactions occur between __________________.
- The strength of attraction between molecules of methanal gas is ____________
- Dipole-dipole forces are a result of electrostatic attraction between ________________
- Upon raising the temperature of polar molecules the strength of dipole-dipole forces _________________.

6. Effects of Dipole-Dipole Forces on Boiling Points

Bromine compared to iodine monochloride.

- Bromine has ________ electrons and iodine monochloride has __________electrons. NOTE: compounds that have the same # of electrons are called **isoelectronic.**
- Using electronegativity differences, which molecule is polar? ________________
- Which molecule has a permanent dipole? _________________ Drawing:
- Which molecular compound has the higher boiling point? _____________

Silicon tetrahydride compared to phosphorus trihydride.

- SiH_4 has _____________ electrons. PH_3 has __________ electrons.
- Which molecule is polar? ________Why? ____________________________________
- Which molecule has a permanent dipole? _____________ Drawing:
- Which molecule has the higher boiling point? __________

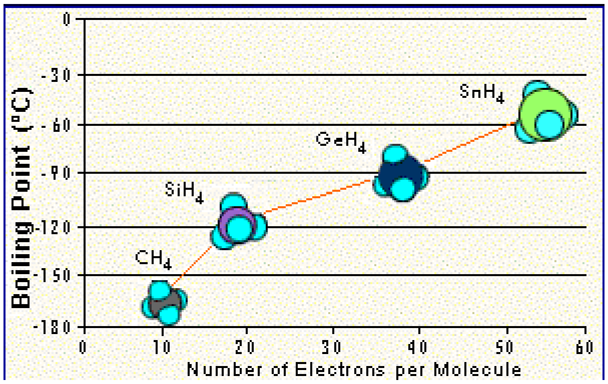
GENERALIZATION about the effect of permanent dipoles on the boiling point of the liquids. Consider: number of electrons, polarity and nature of intermolecular forces.

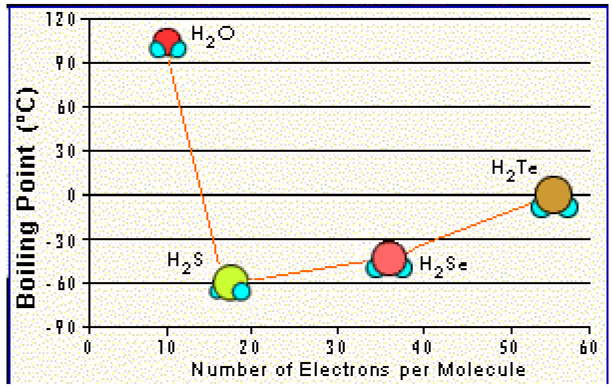
7. Hydrogen Bonding

- Hydrogen bonds can be illustrated using methanol. The hydrogen atom of one methanol atom is attracted to the oxygen atom of another methanol atom. Sketch a hydrogen bond below.
- Why is methanol a liquid at room temperature? In liquid phase, the molecules of methanol are ____
- Draw the hydrogen bond between hydrogen fluoride molecules.
- The strength of attraction between molecules of methanol vapor is _____________
- Hydrogen bonds are the result of electrostatic attraction between ____
- Hydrogen bonding in hydrogen fluoride is due to the ________________________

8. Factors Affecting Hydrogen Bonding

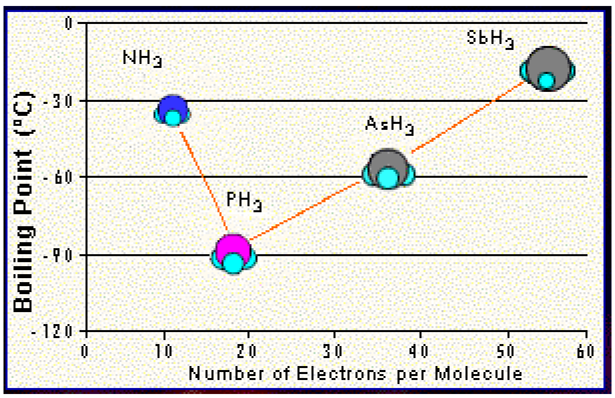
- Based on empirical evidence of abnormally high boiling points, we can conclude that the atoms ________, __________ & ________, when bonded to hydrogen, exhibit hydrogen bonding.

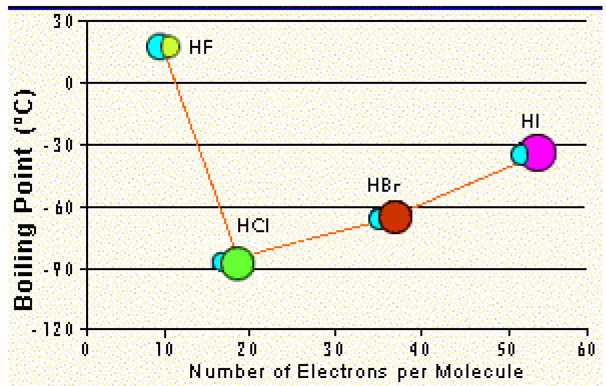




- Does carbon bonded to hydrogen follow the same unique boiling-point pattern as nitrogen, oxygen and fluorine bonded to hydrogen? ____________
- Which molecule does not exhibit hydrogen bonding - CH_4, NH_3, H_2O, or HF?
- Carbon covalently bonded to hydrogen atoms do not exhibit hydrogen bonding because

  ____





- Comparing ammonia and hydrogen chloride, the molecular compound with the higher boiling point is ____________________
- Comparing electronegativities of nitrogen and chlorine, the element with the higher electronegativity is ____________
- Ammonia and hydrogen chloride have central atoms with similar electronegativities. The absence of hydrogen bonding in hydrogen chloride is due to the

  ____
- Compare the boiling points of ammonia, water and hydrogen fluoride. The compounds ranked in order from lowest to highest boiling points are _________________________.
- Compare the electronegativities of nitrogen, oxygen and fluorine. The elements ranked in order from lowest to highest electronegativity are ____________________________.
- The low boiling point of ammonia can best be explained by _____________________

  ____
- Why does water have a higher boiling point than ammonia? ______________________

  ____
- Why does water have a higher boiling point than hydrogen fluoride? _______________

  ____

- The higher boiling point of water compared to ammonia can best be explained by ____
- The higher boiling point of water compared to hydrogen fluoride can best be explained by ____

*9. **Comparison of Intermolecular Attractions***

- The boiling points of molecular substances are affected by the types of intermolecular forces acting between the molecules. The three types of intermolecular forces are: _________________, ____________________ & _______________________
- The unusually high boiling point of hydrogen fluoride is due to _________________

<u>COMPARING hydrogen halides in order from HCl to HBr to HI:</u>

- What are the two types of intermolecular attractions acting between these molecules? ______________________________________
- What happens to the number of electrons per molecules? ___________ __________and what happens to the dispersion forces?___________________
- What effect will increased number of electrons and increased dispersion forces have on the boiling points of these molecules? __________________
- What happens to the electronegativity of the central atoms? __________________ and what happens to the dipole-dipole forces? _______________
- What effect will decreased electronegativity of the halogen atom and the resultant decreased dipole-dipole forces have on the boiling point? __________________

*10. **Boiling Point Diversity***

- Why is the boiling point of methane lower than the boiling point of methanal and methanol? Consider in your response: polarity and types of intermolecular attractions.

- Why is the boiling point of methanol higher than the boiling point of methanal and methanol? Consider in your response: polarity and types of intermolecular attractions.

- What types of intermolecular forces are acting within the substances methane, methanal and methanol. Justify your response.

METHANE:

METHANAL:

METHANOL:

11. ***Closure (Summary)***

- The boiling point of a molecular substance is a measure of the ____
- Arrange the molecules pentane, silicon tetrahydride, 2,2-dimethyl propane and hydrogen gas from highest to lowest boiling points. ______________________

EXPLAINATION:

- Arrange methanol (CH_3OH), methane(CH_4) , methanal(CH_2O) and oxygen gas(O_2) from highest to lowest boiling points . _________________________________

EXPLAINATION:

- Arrange hydrogen sulphide (H_2S), water(H_2O) , oxygen(O_2) and hydrogen telenide(H_2Te) from highest to lowest boiling points . _________________________

EXPLAINATION:

- Molecules from highest to lowest boiling points are _________: A) small nonpolar molecules; B) small polar molecule; C) small polar molecule with hydrogen bonds.
- Molecules from highest to lowest boiling points are _________: A) molecule containing C & H; B) molecule containing H & O ; C) molecule containing H & S
- SUMMARY:

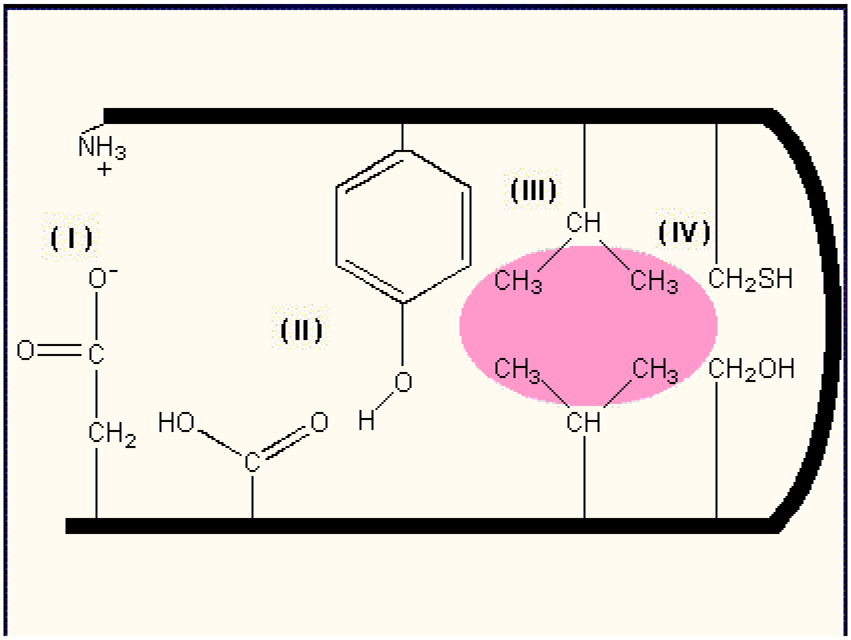
Intermolecular attractions:
Dispersion forces:
Dipole-dipole forces:
Hydrogen bonding:
Boiling points depend on __________________________ and ____________________
For Molecules of the equal size the strongest to weakest forces are
For Molecules of unequal size, the _____________ are stronger than the ___________
Molecules with stronger intermolecular attractions have ____________ boiling points because it take more kinetic energy to escape the liquid phase.

LESSON 4.2 INTRA/INTER COMPARED

1. ***Introduction: C***ell molecules are held together by intra & influenced by intermolecular forces
2. ***Intra/Inter***
   - Water will illustrate the intra and inter-molecular forces.
   - Which forces act within? _________________
   - Which of the following refer to intra-molecular forces? (dispersion, dipole-dipole, hydrogen or covalent)
   - Which forces of attraction are a result of electrostatic attractions?
   - When water is heated it vaporizes rather than decomposing into hydrogen and oxygen. Therefore the _________________ forces are stronger.
   - Intramolecular bonds are found in _____________________________states.
   - Intermolecular bonds are effective in ____________________________states.
   - The strength of intra-molecular bonds determines the __________________ properties.
     Ie) $H_2O_{(g)}$ + energy $\rightarrow$
   - The strength of inter-molecular bonds determines the __________________ properties.
     Ie) $H_2O_{(l)}$ + energy $\rightarrow$
   - Complete the following chart comparing intra-molecular and inter-molecular forces

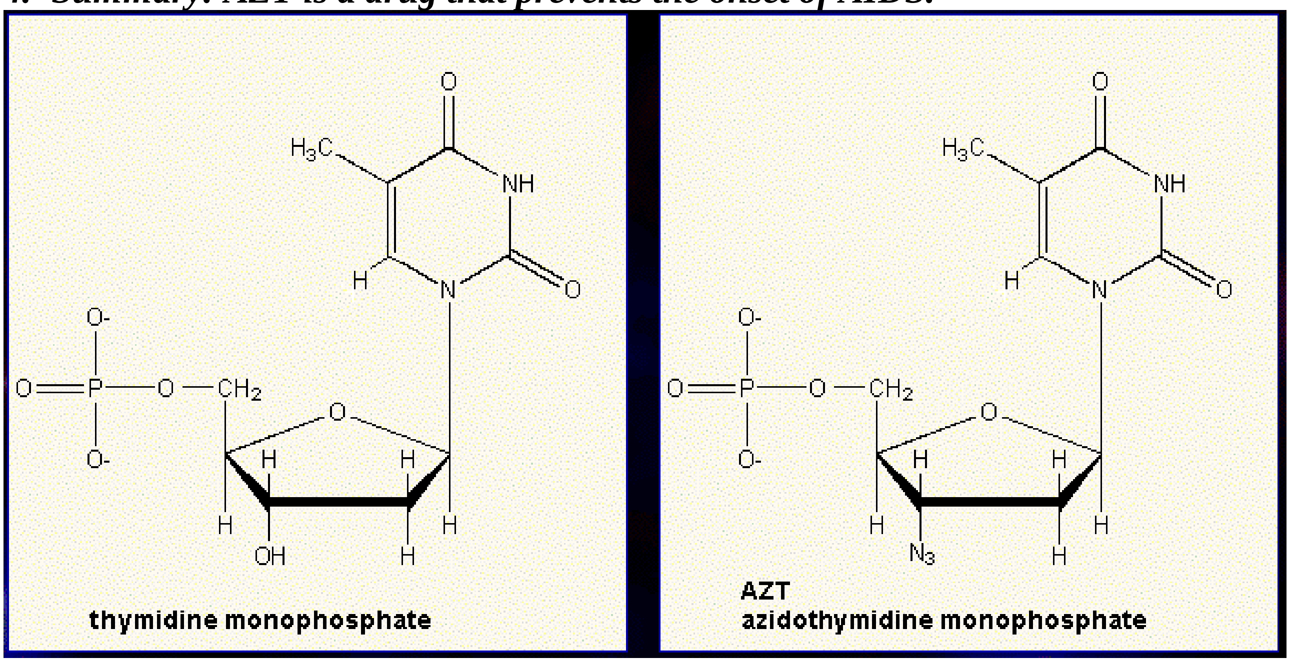
Intramolecular bonds	**Intermolecular bonds**

3. ***Bonding and macromolecules***
   - DNA (Deoxyribonucleic acid) and hemoglobin are macromolecules influenced by intra and inter-molecular bonds.
   - Watson & Crick discovered that DNA nucleotide bases are paired in a certain way. Pair the nucleotides so they form hydrogen bonds: cytosine pairs with _________; guanine pairs with ___________; thymine pairs with ___________; and adenine pairs with ________
   - One strand of the molecules that make up DNA is composed of thousands of atoms that are ________________________ bonded.
   - Two strands of DNA adhere to one another due to ___________________________
   - Intramolecular bonds and intermolecular attractions shape the hemoglobin macromolecule.
   - The primary structure of protein is a result of ____________________ bonding.



- Amino acids combine to form long polypeptide chains through ____________bonding.
  - The intermolecular attractions that give protein its 3D shape are: _____________________
  - The intermolecular attractions between groups labeled "III" is due to _______________
  - The intermolecular attraction between functional groups labeled "IV" is due to ________
  - The intermolecular attraction between functional groups labeled "II" is due to ___________

4. Summary: AZT is a drug that prevents the onset of AIDS.



- Circle the covalently bonded atoms that make thymidine different from AZT.
- Circle the region of the thymidine and AZT where intermolecular attractions take place.
- AZT is attracted to _______________ base of a DNA strand.
- The bond between the base and AZT is ______________________
- The N_3 site on AZT effectively prevents the linking of the backbone. AZT interrupts ___________________________
- Researches use their knowledge of chemical bonding to design drugs to treat HIV and prevent the onset of AIDS. The interaction that did NOT play a role in the use of AZT is ____________________.

LESSON 4.3: PROPERTIES OF MOLECULAR SUBSTANCES

1. ***Introduction***
   - How do the properties of water compare to the properties of other molecular substances?

Substance	**Ammonia**	**Methane**	**Methanol**	**Pentacosane (wax)**	**Sucrose**	**Sulfur**	**Water**
Formula							
Shape							
Uses in your house							
State							
Melting Point							
Boiling Point							
Conductivity							
Solubility in water							
Conductivity of solution							

2. ***States of Molecular substances***
   - ***Conclusion:***
   - ***PLASMA:***
3. ***Melting point of molecular substances: the temperature where a substances turns from a ______________ to a ________________.***
   - ***Apparatus:***
   - ***Conclusion:***
   - How do the melting points of molecular substances compare to the ionic substances?

4. ***Boiling point of molecular substances: the temperature where a substance turns from a _____________________ to a ____________________.***
   - ***Apparatus:***
   - ***Conclusion:***
   - ***Some macromolecules _________________ rather than melt or vaporize***
5. ***Conductivity of molecular substances: ability of _________ to move***
   - ***Apparatus:***
   - ***Conclusion:***
   - ***Tap water contains _________ which make it conduct electricity.***
6. ***Solubility of molecular substances: the amount of ________ that can dissolve***
   - ***Conclusion:***

7. ***Conductivity of molecular substances***
   - ***Apparatus:***
   - ***Conclusion:***

8. Summary

- In what phase do molecular substances exist?

- How do the melting points of molecular compounds compare to water?

- What is the boiling point range for molecular compounds that you have compared?

- Do molecular compounds conduct electricity in gas, liquid or solid state?

- When considering the solubility of molecular substances, the generalization that applies is that molecular substances ___________________________

- When considering the solubility of molecular substances, the generalization that applies to most molecular substances is ______________________________
- The generalization that applies regarding the conductivity of aqueous solutions of molecular substances is that they _____________________
- Which statements are correct statements according to the compounds studied?

1) Molecular substances with melting points above 0C have low solubility in water.
2) Solid molecular compounds do not conduct electricity
3) Molecular compounds that are soluble in water form conducting solutions.
4) Non-polar molecules have the lowest boiling points.
5) Polar molecules are soluble in water.

CONCLUSION:

SUMMARY

*** Strength of all the bonds from strongest to weakest**

Network covalent → metallic & ionic(vary) → HB → DD → LD (based on # of e)

*** Limitations of bonding model**

1. Structures of common gases such as NO_2 & O_3 cannot be explained easily
2. Special properties of gases like oxygen are difficult to explain
3. Formation of complex ions like nitrate, nitrite, carbonate, phosphate and sulphate are difficult to explain
4. Graphite and diamond are different structural forms of carbon. Reasons for the variety are difficult to explain

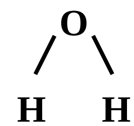
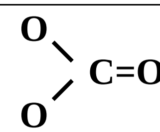
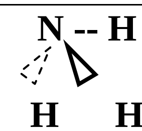
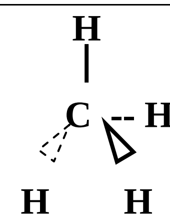
*** Summary of two bond types**

INTERMOLECULAR BONDS	INTRAMOLECULAR BONDS
Types: Van der Waals(London dispersion & dipole-dipole), Hydrogen	Types: Ionic, covalent, metallic, network covalent
Between molecules	Within molecules
Small energy change when broken	Large energy change when broken
Creates physical properties (melting point, boiling point, surface tension, solubility)	Creates chemical properties
Distance between charges is larger	Distance between charges is smaller
Polarity affects strength	Electronegativity affects type & structure
Generally weaker bonds	Generally stronger bonds

*** Electronegativity difference can be use to determine bond type**

Electronegativity difference	Type of bond	Description
> or = 1.7	Ionic	Transfer of electrons between metal & nonmetal
< 1.7	Polar covalent	Electrons shared between unlike nonmetal atoms
0	Nonpolar covalent	Electrons shared between like nonmetal atoms
0	Metallic	Electrons move freely between metal ions

VSEPR (Valence Shell Electron Pair Repulsion) RULES:

Shape	Generalizations	Example
Linear	• **2 atoms total OR 3 atoms with central atom having NO lone pairs** • **polar if pendant atoms are different** • **Group 17 central atoms are always linear**	**H-Cl** **H-C≡N**
Bent (V-shaped)	• **3 atoms total with central atom having lone pairs** • **always polar** • **Group 16 central atoms are always bent** • **The angle between the pendant atoms is 105**	
Trigonal planar	• **4 atoms total with central atom having NO lone pairs** • **polar if pendant atoms are different** • **Group 16 central atoms with a double bond are always linear** • **The angle between the pendant atoms is 120**	
Pyramidal	• **4 atoms total with central atom having lone pairs** • **always polar** • **Group 15 central atoms may be pyramidal** • **The angle between pendant atoms is 109**	
Tetrahedral	• **5 atoms total with central atom having NO lone pairs** • **polar if pendant atoms are different** • **Group 14 central atoms may be tetrahedral** • **The angle between pendant atoms is**	

POLARITY RULES - Polarity depends on:

1) Electronegativity difference: the greater the difference the more polar the substance.
2) Shapes: Bent & Pyramidal shapes are always polar
3) Pendant atoms: If the pendant atoms are different than the molecule is polar
4) Lone pairs can enhance polarity

Water has a high melting point because:

- It is bent and polar (electronegativity difference is 1.4 between hydrogen and oxygen)
- The lone pairs enhance the polarity
- Water has LD, DD and HB
- Water has four or more spots where hydrogen bonding can form – the hydrogen bonds are strong.